Coastal Ocean Modeling and Observation Program

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Grant Number: N000149710797

LONG-TERM GOALS

The long-term goal of our coordinated ONR (COMOP-II/HyCODE) and NOPP research efforts is the development and validation of a relocatable coastal ocean forecasting system. The forecasting system will consist of a coupled (atmospheric / hydrodynamic / biological / data-assimilative) numerical model and a multi-platform real-time adaptive sampling network for use in physical/bio-optical and sediment transport applications worldwide.

OBJECTIVES

Specific objectives of the COMOP-II effort include: (a) Conduct fourth and final Coastal Predictive Skill Experiment (CPSE) at LEO in collaboration with HyCODE, utilizing a comprehensive coastal prediction system incorporating atmospheric, benthic and bio-optical sub-models; (b) Extend the modeling system to provide the larger-scale modeling context for the CBLAST (Low) experiment in 2002 and 2003; (c) Synthesize datasets and model simulations from the four (1998-2001) LEO field seasons; (d) Evaluate ocean model metrics in multiple regions; and (e) Implement a two-way-coupled atmosphere-ocean prediction system utilizing the ROMS and COAMPS models.

APPROACH

The Coastal Ocean Modeling and Observation Program (COMOP) supports work for two separate field efforts conducted in different locations. The first is the series of Coastal Predictive Skill Experiments (CPSEs) conducted at the Long-term Ecosystem Observatory (LEO) offshore of Tuckerton, New Jersey. Model and observation network improvements tested each winter with existing data are used in an operational setting the following summer. Our phenomenological focus is on the physics of the recurrent upwelling centers that form along the southern New Jersey coast and their impact on phytoplankton distributions, in-water optical properties and dissolved oxygen. Coordinated shipboard (physical and bio-optical) and multiple AUV adaptive sampling surveys of the upwelling centers are conducted based on real-time remote sensing and *in situ* observations and model forecasts. Predictions are carried out using a hierarchy of nested and/or coupled sub-models, including: the COAMPS regional mesoscale atmospheric model, the ROMS regional ocean model http://marine.rutgers.edu/po/models/roms/index.php, and a multi-component bio-optical model *(EcoSim)*, and supporting packages for data assimilation, visualization and model assessment.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2002**	2. REPORT TYPE	3. DATES COVERED **00-00-2002 to 00-00-2002**

4. TITLE AND SUBTITLE
Coastal Ocean Modeling and Observation Program

5a. CONTRACT NUMBER
5b. GRANT NUMBER
5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER
5e. TASK NUMBER
5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Rutgers University,Institute of Marine and Coastal Sciences,,71 Dudley Road,,New Brunswick,,NJ, 08901

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR’S ACRONYM(S)

11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The long-term goal of our coordinated ONR (COMOP-II/HyCODE) and NOPP research efforts is the development and validation of a relocatable coastal ocean forecasting system. The forecasting system will consist of a coupled (atmospheric / hydrodynamic / biological / data-assimilative) numerical model and a multi-platform real-time adaptive sampling network for use in physical/bio-optical and sediment transport applications worldwide.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**7**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

A second regional implementation of our Coastal Forecasting System is underway at the site of the CBLAST-Low experiment offshore of Martha's Vineyard, Massachusetts. There are two threads to our ocean modeling work for CBLAST. Firstly, moored observations of air-sea momentum and buoyancy fluxes, subsurface velocity, and stratification, provide validation data with which we are evaluating modeled mixed layer and vertical turbulence closure parameterizations. Secondly, hindcast simulations driven by tides, shelf-wide hydrographic observations and measured (CBLAST) or modeled (COAMPS) air-sea fluxes quantify the role of lateral advection in local depth-integrated heat budget calculations, thereby identifying the principal unobserved term in heat budget diagnostics applied to the *in situ* data.

WORK COMPLETED

LEO-15. With fieldwork for the four LEO CPSEs completed in the summer of 2001, FY2002 was a transition year for COMOP. This part of the project has entered into the analysis and synthesis phase. Objectives in the fall of 2002 and winter were to develop a preliminary evaluation of both the COAMPS atmospheric forecasts and the ROMS ocean forecasts. Results (see below) were presented in two posters at the Honolulu Ocean Sciences meeting in February (Bowers et al., 2002; Lichtenwalner et al., 2002; http://marine.rutgers.edu/mrs/coolresults/agu2002/index.html).

CBLAST-Low. ROMS has been configured for a domain bounded by 71.3W to 69.1W, 41.7N to 40.5N. This encompasses Vineyard Sound, the Nantucket Shoals, extending southward to the 90m isobath. The model grid size is 1 km. A suite of simulations have been conducted with increasing realism, culminating in the most realistic case to date which includes (1) tidal forcing at the perimeter specified from the ADCIRC northwest Atlantic model provided by R. Luettich (the 7 most significant harmonic constituents), (2) inflow/outflow open boundaries using a bi-monthly climatology provided by C. Naimie, (3) surface air-sea momentum fluxes computed using the Fairall *et al.* bulk formulae and atmospheric conditions for June-August 2001 as observed at the MVCO coastal met station. (These meteorological conditions were assumed to apply over the entire model domain).

RESULTS

LEO-15. Three atmospheric forecasts were available for comparison, the Global NOGAPS, the operational COAMPS, and an experiment high-resolution COAMPS run by NRL-Monterey. The atmospheric forecasts were compared to observations collected across the state of New Jersey and offshore by computing the normalized RMS error (as suggested by NRL-Monterey) for wind speed, direction, temperature, and humidity. On average, the experimental high-resolution COAMPS did as good or better than the other models by this statistical measure, with the most significant improvement in the overwater comparisons.

The three models were then examined for their forecasts of specific events. The examples chosen for study focused on the ability to forecast a mesoscale seabreeze and a rapidly moving synoptic scale storm. The experimental high-resolution COAMPS did a much better job of forecasting the development and inshore movement of the seabreeze front. In the second case, the rapidly moving low actually tracked in between the Operational COAMPS and the experimental high-resolution COAMPS, but the high-resolution COAMPS more accurately predicted the intensity of the storm.

For the LEO CPSEs, ROMS was configured for the New York Bight with a typical one km resolution grid. Tidal forcing was applied at the boundaries using ADCIRC harmonic forcing. Atmospheric forcing was provided by the Operational COAMPS (27 km) and the experimental high-resolution (5 km) COAMPS. Air-sea fluxes were calculated by the COARE algorithm. The turbulent fluxes were parameterized using the KPP and MY2.5 in the surface layer and the inverted KPP and MY2.5 in the bottom boundary layer. Bottom stress was calculated using a combined wave and current bottom boundary layer model.

An ensemble of three-day forecasts was produced twice per week during the experiment. The ensemble consisted of different combinations of atmospheric forcing and internal turbulent closure. Assimilation datasets for each forecast's initial condition included satellite SST maps, CODAR surface current maps, and subsurface CTD data. Ensembles of forecasts run in real-time were evaluated using a cross-shelf Relocatable Mooring Array (RMA) consisting of bottom-mounted ADCPs and moored thermister strings spaced every 4 km in the cross-shelf direction.

At the offshore end of the validation transect, a persistent two-layer system is observed with layers separated by a sharp thermocline. Inshore, the thermocline responds to the varying wind, with alternating upwelling and downwelling fronts developing. The alongshore flow is strongly barotropic, the cross-shore flow is clearly baroclinic. Metrics to evaluate the model's ability to reproduce the observed behavior were developed. These include depth of the maximum temperature gradient, slope of the maximum temperature gradient, average temperature above this depth, average temperature below this depth, barotropic alongshore transport, and baroclinic cross-shore transport in each layer.

A specific case chosen for the initial study was forecast cycle 3, a strong downwelling case. In response to northeast winds, a sharp downwelling front formed nearshore and moved rapidly offshore through the validation array. An ensemble of 4 forecasts with either Operational or High-Resolution COAMPS and KPP or MY2.5 closure was compared using the model metrics. The ROMS forecast that compares best is forced by the Experimental High-Resolution COAMPS with KPP closure. The biggest differences between the KPP and MY2.5 closure occur in the bottom boundary layer, where KPP predicts stronger mixing.

Throughout the spring and summer of 2002, this preliminary validation of ROMS forecasts was followed up by a more complete evaluation matrix of ROMS hindcasts.
To the ensemble, we have added different real-time assimilation schemes (OI versus nudging), different assimilation datasets (SSTs, CTDs, short range CODAR, long-range CODAR) and different vertical extension techniques for surface data (ad hoc profiles, EOFs). Results from this new ensemble of forecasts are now being evaluated with the cross-shelf RMA using the model metrics.

CBLAST-Low. A 90-day simulation for the summer of 2001 was compared to thermistor string data from the 2001 ASIT mooring. The comparison reveals several shortcomings of this initial model configuration, and improvements are being implemented in summer 2002 to address these. The principal shortcoming is that the simulated temperature at the ASIT mooring site undergoes a significant warming trend. Simulated Lagrangian particles in the model indicate that the passage of warm Vineyard Sound water through Muskegat Channel, and subsequent advection past the model ASIT site, contribute to this erroneous heating. Further analysis of the ROMS results is proceeding to identify whether this advection pathway is correct or possibly adversely influenced by incomplete resolution of bathymetry and coastline details that affect the tidal exchange though Muskegat Channel. Alternatively, the model Vineyard Sound waters may be overheating due to the air-sea flux

parameterization or the use of MVCO conditions over the sound. The introduction of spatially variable high-resolution COAMPS surface conditions will show whether the latter hypothesis is correct. These early results have indicated clear directions for model improvement and validation. The simulated heat budget at the location of the CBLAST LOW 2002 moorings and the tower will be examined in detail looking for potential influences of advection in the heat budget (including the flow through Muskegat Channel, but also from the Nantucket Shoals, and cooling from upwelling to the southwest). Also to be examined are resolution issues for the momentum budget that might help site the locations of the extended array instruments in subsequent field studies.

IMPACT/APPLICATIONS

Participants in the July 2001 CPSE included over 150 scientists, students and technicians from over 25 academic, government and industrial institutions. The collaborative nature of the interdisciplinary scientific studies at LEO continues to attract new partners.

NRL atmospheric forecasters participated as full partners for the first time. Their tailored COAMPS atmospheric forecasts produced an excellent set of ocean forecasts, featuring large excursions of a bottom front in response to rapid wind shifts. Combined with the most extensive cross-shelf array we have ever deployed and recovered, an extensive database for model validation and assimilation has been generated.

Web access for the LEO datasets currently averages over 60,000 hits per day during the summer, demonstrating its usefulness for public outreach and educational programs. This has led to the development of a new public access web site featured on several New York and Philadelphia TV stations this summer.

Louis Bowers, a Rutgers undergraduate working on the atmospheric model validation for COMOP has just started graduate school at Rutgers. He has completed training on how to run the COAMPS model at NRL-Monterey. His intended thesis is to use COAMPS and ROMS to study the effect of coastal upwelling on seabreeze development.

TRANSITIONS

Worldwide use of the ROMS model continues to grow, including applications involving the full East and West Coasts, numerous smaller sub-domains along these coasts (LEO, Gulf of Maine, Hudson River, CalCOFI), the Gulf of Alaska, and the Bering Sea. ROMS serves as the basis for the new Navy Terrain-following Ocean Modeling System (TOMS; http://www.ocean-modeling.org/).

COMOP scientists serve as members of the steering committee for the Gulf of Maine Ocean Observatory (GoMOOS), the NorthEast Ocean Observing System (NEOOS), and the Consortium of East Coast Ocean Observatories, .

Real-time data sets produced by the LEO observatory are currently being used by the Coast Guard and the Navy for operational support in the New York Bight.

RELATED PROJECTS

The ONR-sponsored HyCODE project, led by Oscar Schofield, sponsored most of the bio-optical component of the July, 2001 HyCODE/COMOP Coastal Predictive Skill Experiment.

The ONR-sponsored CODAR Rapid Environmental Assessment project is expanding the CODAR observation network offshore to the shelf break with new Long-range CODARs and onshore to the beach with Bistatic CODARs.

The ONR-Sponsored Terrain-following Ocean Modeling System (TOMS) project, led by Hernan Arango, is merging portions of the widely-used Princeton Ocean Model (POM) with ROMS to produce TOMS.

ONR and the Great State of New Jersey have sponsored the acquisition of 4 Webb Glider AUVs and the development of new communications and control software for applications in the New York Bight.

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